Florence, Italy 12-16 July 2015
ICSV22
The 22nd International Congress on Sound and Vibration

LIFE+2010 QUADMAP PROJECT (QUIET AREAS DEFINITION AND MANAGEMENT IN ACTION PLANS): RESULTS OF POST OPERAM DATA ANALYSIS AND THE OPTIMIZED METHODOLOGY

Chiara Bartalucci, Francesco Borchi, Monica Carfagni, Lapo Governi and Giovanni Zonfrillo

Department of Industrial Engineering, University of Florence, via di S. Marta 3, 50139 Firenze, Italy
e-mail: francesco.borchi@unifi.it

Raffaella Bellomini

Vie En.Ro.Se. Ingegneria, via Stradivari 19, 50127 Firenze, Italy

Henk Wolfert

DCMR Environmental Protection Agency, Parallelweg 1, 3112 NA Schiedam, the Netherlands

Itziar Aspuru

TECNALIA Research & Innovation, Parque Tecnológico de Bizkaia c/Geldo, Edificio 700, 48160 Derio, Spain

Piotr Gaudibert

Bruitparif, 90-92 avenue du General Leclerc, 93500 Pantin, France

The EU Directive 49/2002/EC on Environmental Noise refers to Quiet Urban Areas (QUAs) as places whose acoustic climate should be preserved because a noise indicator is lower than a threshold established by each Member State. This definition appears to be extremely generic and doesn't provide usable procedures to be applied in each Country. Proposing a solution to overcome the lack of harmonized methodologies for QUAs is the main aim of QUADMAP (QUiet Areas Definition and Management in Action Plans) Project. The results of the Project will facilitate urban planners to apply standard procedures for identification, delimitation and prioritization of QUAs. The Project has a high level of demonstrativeness guaranteed by the fact that the proposed methodology has been tested in a number of pilot areas in Florence (Italy), Bilbao (Spain) and Rotterdam (The Netherlands). The Project started on 1st September 2011 and lasts three years and half. At the beginning of 2013 the harmonized methodology has been defined. The proposed procedures have been tested since February 2013 in all pilot cases and the methodology has been improved, in line with experiences gained during data collection and analysis of the ante-operam scenarios. Since the beginning of 2014, the realization of interventions started, following indications coming from end-users questionnaires, expert analysis, technicians and application of complementary criteria. In the pilot areas of Bilbao interventions have been completed by June 2014, while in Flor-

ence and Rotterdam they have been concluded by the end of the same year. In the meantime, post-operam data collection and analysis have started. In this paper results of the post operam data analysis are described and compared with those obtained on the ante-operam phase. Moreover, the main innovative elements introduced in the optimized methodology are illustrated.

1. Introduction

The European Directive 2002/49/EC on the Assessment and Management of Environmental Noise (further abbreviated as END) was adopted to define a common approach to avoid, prevent or reduce the harmful effects due to noise exposure and to preserve the environmental noise quality where it is good. One of the main environmental problems targeted in this sense is the need of improvement in the definition of QUAs (Quiet Urban Areas). The END defines "Quiet Area" as "an area, delimited by the competent authority, which is not exposed, for instance, to a value of L_{den} or of another appropriate noise indicator greater of a certain threshold (set by the Member State) from any noise source". This is not clear enough to allow an appropriate assessment and management (action planning) of QUAs in urban environment [1-3]. A further issue concerns the fact that areas where citizens expect to find a quiet environment often do not meet the noise limits associated to them by the national law, assuming there are (preferred) noise limits and a law exists. In those countries where national and local factors in identifying and protecting QUAs are considered, significantly different and mainly very general approaches have been taken into account [4]. The consequence of this "freedom of choice" results in non-homogeneous collections of data as well as in a divergent approach across the EU.

QUADMAP Project started in September 2011 in order to answer to the main open issues regarding QUAs at European level. In fact, the final aim of the Project is to develop a complete, practical and demonstrated methodology to select, analyse and manage QUAs. As a complementary aspect, approaches to design QUAs were also addressed during the working process.

2. Methodology updating starting from ante-operam data

At the beginning of 2013 QUADMAP Project delivered a first version of the methodology about the QUAs selection, analysis and managing. The detailed description of each section of the method, data to be acquired in each pilot area and related tools are presented in previous papers [5-6].

Since February 2013 the methodology was applied in several pilot areas: six schoolyards in Florence, a square and a peri-urban green corridor in Bilbao and two public parks in Rotterdam. From data collected during the ante-operam phase two main objectives have been achieved: to update the draft version of the methodology about QUAs selection and analysis and to define the most critical aspects of each pilot area and, consequently, to propose possible interventions to solve them in the management phase.

2.1 Methodology updating: selection and analysis phase

According to indications given in each Tool described in the original methodology the following typologies of data have been collected in each pilot area:

- quantitative data (noise maps, short and long term measurements, wave recordings);
- qualitative data (end-users questionnaires, general and non-acoustic evaluations made by experts).

In Table 1 the main analysis made on ante-operam data and most important contribution given for the methodology updating are shown.

Table 1. Results of analysis made on ante-operam data.

Methodology section	Analysis made	Results and contributions to the updated methodology
Selection phase: rQUA (noise gradient) criterion	Verification of the applicability into the pilot cases.	Validity of the tool confirmed [7].
HUAs subdivision	Non-parametric statistical analysis, to check if answers to specific questions could be considered not equally distributed in each HUA, using end-users questionnaires.	Validity of the tool confirmed [7].
Analysis phase: expert analysis	Evaluation of selected variables carried out by experts.	No significant changes to the originally selected variables, according to the report delivered by experts for all pilot cases.
Analysis phase: end-users questionnaires and measurements	Ordinal regression models, to understand whether the acoustic and more general perception of a QUA by the users in the questionnaires can be explained by objective acoustical parameters.	Short term measurements: the most appropriate parameter to describe the perception of users is the LA50 [7]. Long term measurements: they allow the validation of the results of the noise maps and the definition of the best day times to submit the questionnaire and to carry out the short term measurements. Wave recordings: no significant correlations have been observed with questionnaires. For this reason they have been confirmed as a complementary variable [7]. End-users questionnaire: the number of questions has been reduced and some questions have been rephrased.

A further description of each analysis made on ante-operam data, followed procedures and achieved results are illustrated in previous papers [7-9]. In Fig. 1 the main differences between the original and the updated version of the methodology are presented.

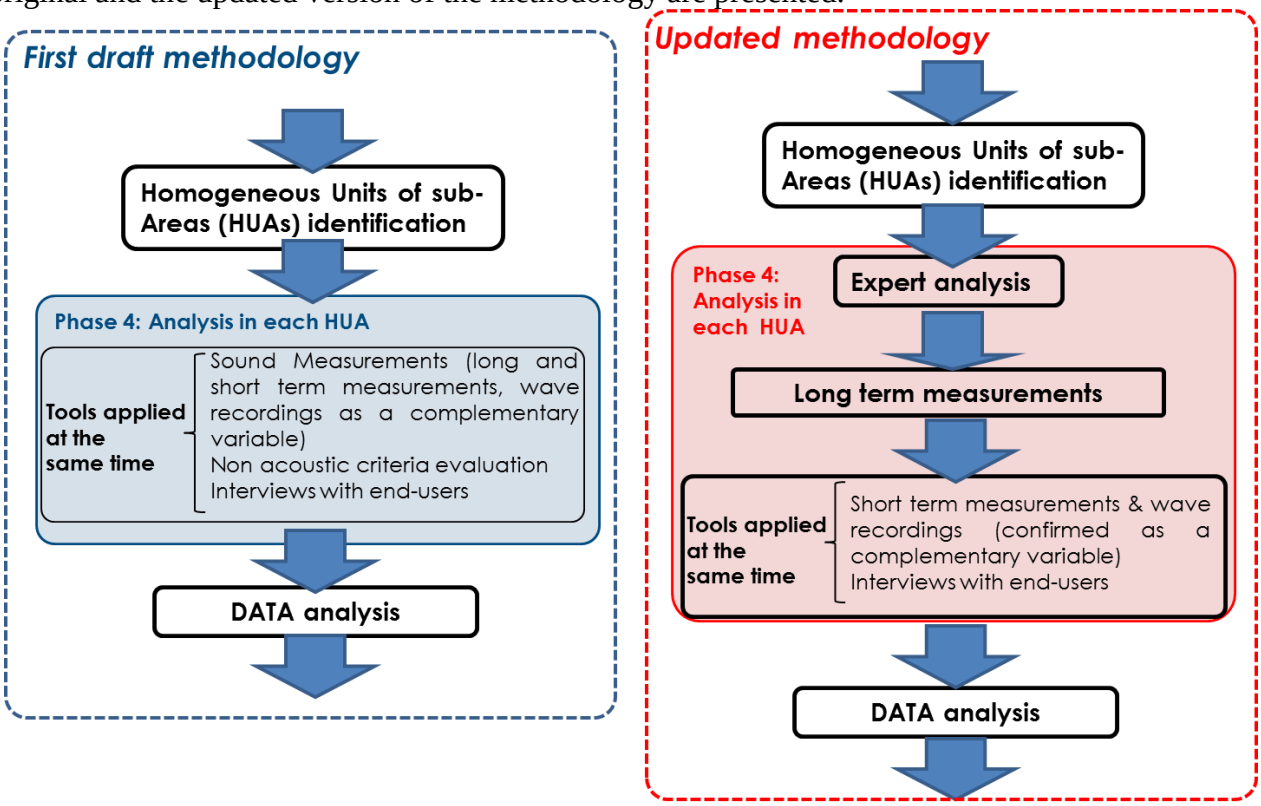

Figure 1. Methodology updating after the ante-operam data analysis.

The main difference which can be observed between the flowcharts illustrated in Fig. 1 and which is not explained on previous papers regards the use of long term measurements. In the original version of the methodology [6] it is suggested to collect long term measurements together with

short ones and end-users questionnaires. However, from the analysis carried out on ante-operam data, it is verified that long term measurements don't provide an added value if collected together with short ones, but they are useful in order to:
- validate the outcomes of noise maps, with reference to the specific and "small" studied areas.
- collect acoustic information about the variability of sound levels versus time in the area and to consequently select the best period to carry out end-users questionnaires and short-term measurements, offering a justified representativeness of the acoustic climate in the periods when citizens use the area.

About the analysis of variability of noise climate, based on the results achieved in the pilot cases, the following are the proposed parameters in order to establish time periods in which the acoustic environment can be considered homogeneous:
- LA50 or LAeq, 1 hour based, as main parameters to evaluate the variability of acoustic climate in terms of average noise levels
- L10-L90, 1 hour based, as main parameter to evaluate the variability of acoustic climate in terms of occurrence of acoustic events.

Proposed conditions for the definition of homogeneity for the time period "T" are the following:
- LAeq or LA50 carried out hourly based are close (±3 dB) to average levels obtained in the T period.
- L10-L90 carried out hourly based, is closed (±3 dB) to the average value obtained in the T period.

The following relations transpose the previous conditions:
$LA50(T) -3 < LA50(hour) < LA50(T) +3$ or $LAeq(T) -3 < LAeq(hour) < LAeq(T) +3$;
$LA10\text{-}LA90(T) -3 < LA10\text{-}LA90(hour) < LA10\text{-}LA90(T) +3$.

2.2 Methodology updating: management phase

Referring to the management procedures, the methodology gives indications about the potential content of an Action Plan for preserving or creating QUAs and about typologies of interventions to be implemented. During the post-operam phase the methodology has been tested in the pilot cases by replicating procedures proposed in the analysis section and comparing the ante to the post-operam results.

2.2.1 Definition of criticalities and suggestions for interventions

During the ante-operam period each section of the methodology proposed by the QUADMAP Project and related tools have been applied in the pilot cases. Results obtained, combining end-users questionnaires, acoustical measurements and expert analysis, allowed to detect the main acoustic and non-acoustic criticalities. From these outcomes it was possible to obtain useful indications for the definition of solutions to be implemented.

In Table 2 criticalities defined in the pilot areas and designed interventions are reported.

Regarding pilot areas selected in Florence, only in four of them relevant interventions eventually took place. In fact, in the P. Fedi schoolyard only a minor intervention, consisting in the installation of additional road signs to reduce the average vehicles speed, has been considered adequate. Indeed, in the P. Uccello school, interventions were not implemented in the open spaces because considered as a minor necessity compared with other actions aimed inside the building and considered a priority by the school leadership. As a consequence, the post-operam analysis referring the pilot areas in Florence has been carried out only in the four schools where relevant interventions were implemented.

Table 2. Criticalities defined in the pilot areas and interventions designed.

Pilot area	Acoustic criticality	Acoustic interventions designed	Non Acoustic criticality	Non Acoustic interventions designed
Vamba/Montessori schoolyard (Florence)	Noise from the nearby road infrastructure.	Noise barrier.	Need of a space for teaching in external.	A part of the barrier is green type. A wooden platform in the garden area protected by the barrier has been designed.
Dionisi Schoolyard (Florence)	Noise from the nearby road infrastructure.	Noise barrier.	Need to discourage people from outside the area to approach and call the children.	Blackboards integrated into the internal side of the barrier.
Manzoni Schoolyard (Florence)	Noise from the nearby road infrastructure.	Noise barrier.	Need of shaded areas with benches and games.	5 trees, 30 concrete cube seats.
De Filippo Schoolyard (Florence)	Noise from the nearby road infrastructure.	Noise barrier.	Need of shaded areas with benches and games.	4 trees, 20 concrete cube seats; 2 sound games.
P. Fedi schoolyard (Florence)	Noise from the nearby road infrastructure.	Additional road signs containing the prescribed speed limit of 30 km/h (minor intervention).	/	/
P. Uccello schoolyard (Florence)	Noise from the nearby road infrastructure.	Noise barrier.	The schoolyard is a little bit used, also for the lack of equipment such elements for the seat	Seats made up of concrete cubes of size 45x45x45 cm with anti-graffiti treatment.
S. Marina green corridor (Bilbao)	None (Background noise of traffic, < L_{den} 55)	/	None	Selective tree thinning of non-autochthonous plants (*Pinus Pinaste*).
G. La Torre square (Bilbao)	Noise from traffic.	Urban barrier for traffic noise combined with a fountain (that creates background water sound and water sound events related with jets), improvement of traffic flow, give priority to pedestrian, increasing greenery (developing small hills)	Need to modify dominant sound sources and increase positive events, to improve safety, accessibility, cleanliness and maintenance.	Increasing the pedestrian accessibility, creating visual permeability, improving the construction quality in materials and services (putting 43 trees in the area and increasing the presence of benches), increasing the resting areas in the square and the area for greenery, increasing the acoustic comfort in the area (pleasant sounds coming from urban furniture with vertical water dispensers).
Southern park (Rotterdam)	Noise from traffic.	Low noise paving.	/	/
Spinoza park (Rotterdam)	Noise from traffic.	Low noise paving.	/	/

2.2.2 Comparison between ante and post-operam data

After the interventions' realization the methodology proposed and updated after the ante-operam phase has been applied again in the pilot cases, in order both to definitely optimize it and to evaluate the interventions' effectiveness. In particular, typologies of achieved data are: noise maps, expert analysis, end-users questionnaires and short term measurements.

Currently the analysis of post-operam data has been completed in the pilot cases of Florence, Bilbao and Rotterdam. Results obtained in Florence and Bilbao from the comparison of ante and post-operam end-users questionnaires and short term measurements are illustrated in the following sections.

Florence

Referring to pilot cases selected in Florence, results obtained during the post-operam phase are overall positive (see Fig. 2). In effect, scores obtained from questionnaires about the general evaluation of each pilot area are higher than those of the ante-operam phase. According to short term measurements associated to questionnaires, average noise levels have proved to be lower during the post-operam surveys. Only for Dionisi school users' perception about the area in its entirety hasn't changed, but this result can be explained since also during the ante-operam phase they were very positive. In that area noise levels, expressed in terms of LAeq or LA50, are approximately the same and lower than 55 dB(A).

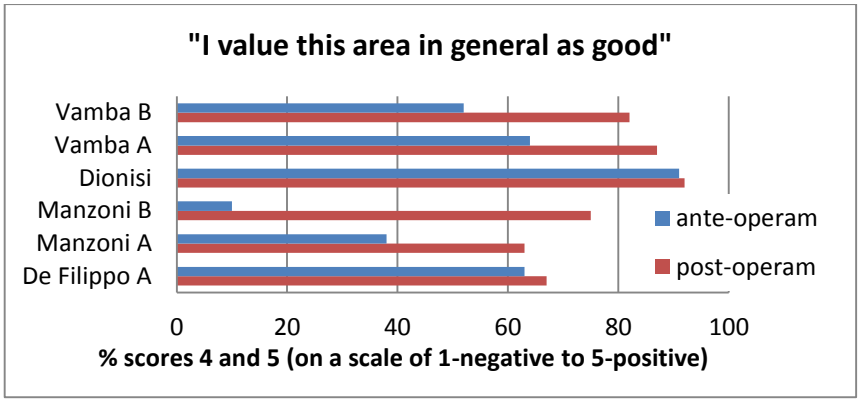

Figure 2. Florence, general evaluation of the area.

Bilbao

Santa Marina green corridor

In the post-operam questionnaires, the distribution of some answers is quite similar to that of ante-operam ones and, in these cases, positive scores are decisively confirmed (see Fig. 3).

In this pilot case the proposed procedures for designing of interventions (based also on expert analysis) seem to be positive according to the improved well-maintenance and accessibility of the area. Referring to short term measurements associated to questionnaires, as expected noise levels haven't changed since only interventions of tree maintenance have been carried out.

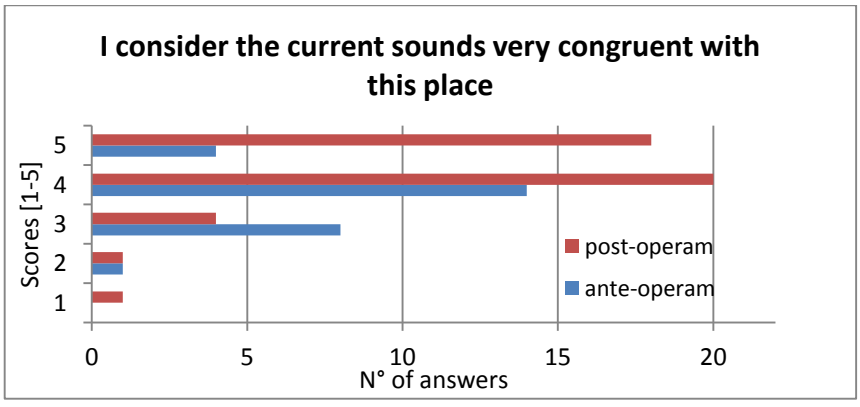

Figure 3. Bilbao-Santa Marina, compatibility between sounds and use of the area.

General La Torre square

In the post-operam questionnaires there is a remarkable change in the perception of the sound atmosphere: a 73.4% of users consider it as calm (40.5 % of increase) and a 78.8% consider it as

pleasant (41.2% of increase). The perception of general conditions in the area has also improved: now is perceived as safer, cleaner, more accessible, more pleasant visually and better maintained.

The perception of the sound atmosphere suffered deep changes since the dominant sources had passes from traffic to water, form birds to children. In this pilot case the proposed procedures for designing of interventions seem to be appreciated according to the post-operam results. Referring to short term measurements associated to questionnaires, noise levels (LAeq, LA50) are slightly increased (2-3 dB) after the realization of interventions. However, the composition of the sonic atmosphere is totally different and there is a noticeable reduction of negative events associated to traffic. These changes contribute to explain the significant improvement in the users' perception.

2.2.3 Indications for Management Plans

From post-operam results the effectiveness of the procedure proposed for the management phase, starting from both acoustical and non-acoustical analysis, is proved. Indeed, the only acoustical evaluation would have led to a wrong conclusion, for example concerning the effectiveness of interventions implemented in both the pilot cases in Bilbao which can be considered as success cases in terms of perception or end users, although the noise levels were not decrease. At the same time, the evaluation of acoustical parameters is certainly necessary to understand the outcomes for the pilot cases of Florence.

From results obtained, the following relevant criteria are proposed for the management phase, in terms of comparison between ante and post-operam:

- evaluations made by experts in order to verify a possible improvement of non-acoustic aspects;
- short term measurements to possibly verify a reduction of levels (mainly referring to parameters of LA50/LAeq) respect to a threshold level (e.g. 55 dB) or, in any case, to the ante-operam scenario;
- answers given to the end-users' questionnaire, in order to verify the possible improvement in end-users perception in the post-operam scenario;
- composition of the acoustic environment in order to verify a reduction of unpleasant sound events and/or an increase of the pleasant sound events in the post-operam scenario.

As a general indication, the improvement of at least one of the previously defined items can be considered as an improvement of the environment of the area, according to the QUADMAP experience.

Management Plans of QUAs can have different goals depending on whether the selected areas have been defined as actually quiet or only potentially quiet during the analysis phase:

- Plan to preserve the quality of the area, in case it can be defined as already quiet
- Plan to increase the value of the area and to promote their use
- Plan to improve the quality of the area, in case of potentially quiet areas.

As a proposal to strengthen the definition of QUAs in the framework of the Action Plans, the management plan of QUAs could be connected with the strategy of maintenance and renovation of the city. The results of the project highlight the importance of identifying opportunities in the city to incorporate the management of potential quiet urban areas and how positively the changes are perceived by citizens when the process is constructive and participatory.

3. Conclusions

The methodology proposed by QUADMAP Project consists in a practical and tested procedure for the selection, analysis and management of a QUA. Referring to the selection and analysis phases, the methodology is validated according to evaluations made on ante-operam data [7].

In this paper the procedure developed for the management phase is evaluated, basing on the comparison between results obtained for the ante and post-operam scenarios. After the interventions realization, the application of the updated version of the methodology proposed by the QUADMAP Project to the pilot areas sets its overall validity. In most pilot areas the comparison between quanti-

tative and qualitative data, respectively achieved during the ante and post-operam phases, confirms the overall effectiveness of interventions implemented.

In February 2015 guidelines devoted to noise experts and illustrating the optimized methodology have been produced and made available on the Project web site (www.quadmap.eu).

Since many Italian cities have shown interest in testing the optimized methodology, a new Project proposal titled "QUADMAP-2-DR" (QUiet Areas Definition and Management in Action Plans -2-Demonstrative Results) has been submitted to the last LIFE+ call. The main aspects of the follow up project are the demonstration of the usability of QUADMAP methodology in different contexts and the improvement of the current method, considering new aspects as air quality and socio-economic items.

ACKNOWLEDGEMENTS

The authors would like to thank all who sustained them with this research, especially the European Commission for its financial contribution to the Project into the LIFE+2010 program.

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